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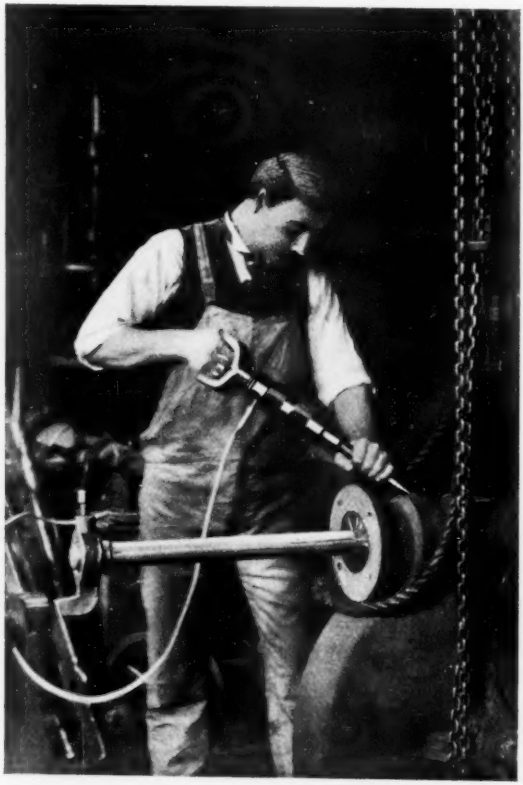
Compressed Air

DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. II. NEW YORK. FEBRUARY, 1898. No. 12



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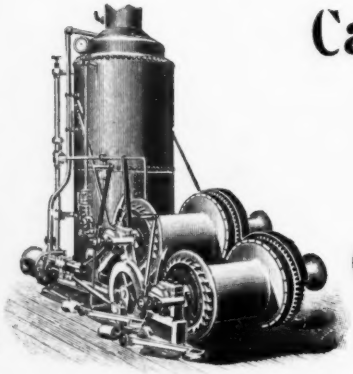

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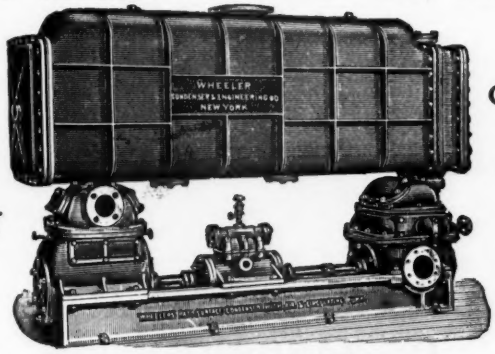

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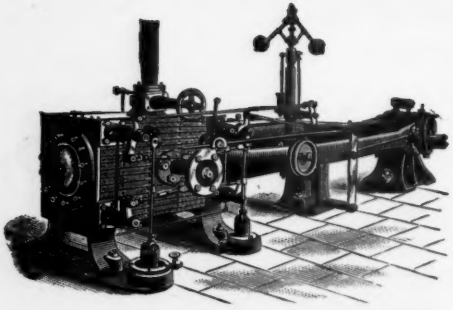

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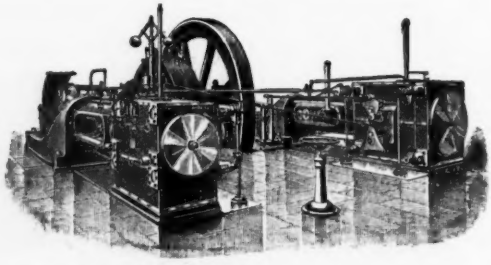

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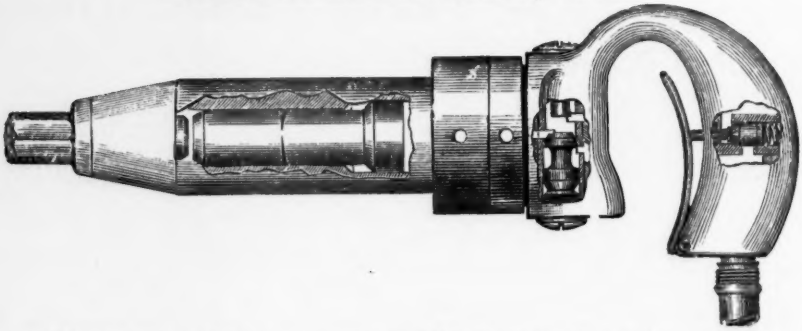

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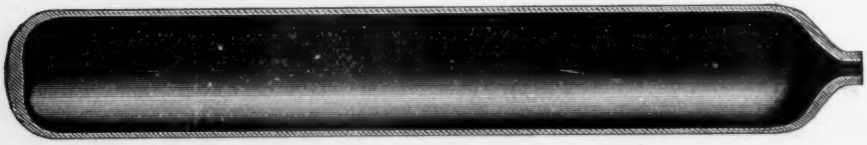

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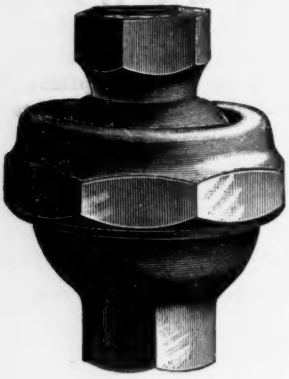

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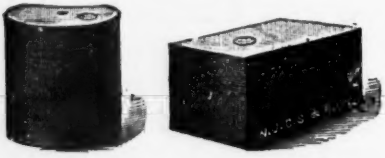

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Compressed Air.

A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

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Subscription, including postage, United States, Canada and Mexico $1.00 a year. All other countries, $1.50 a year. Single copies, 10 cents.

Advertising rates furnished on application.

We invite correspondence from engineers, contractors, inventors and others interested in compressed air.

All communications should be addressed to COMPRESSED AIR, 26 Cortlandt St., New York.

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Those who fail to receive papers promptly will please notify us at once.

Entered as Second-Class Matter at the New York, N. Y., Post Office.

VOL. II. FEBRUARY, 1898. NO. 12.

We are glad to note the successful introduction and use of the pneumatic system of conveying mails in cities. The Batcheller system is now in continuous operation in New York City, special carriers being provided for conveying the mails through a tube 8″ in diameter. In this system the carriers slide through the tube, a condition which is probably limited to tubes of 8″ to 10″ in diameter. It would seem that tubes of small diameter cannot be as serviceable or as economical in post offices or package delivery work owing to the labor required in transferring the packages. Tubes large enough to carry mail bags or common express packages would have many advantages and it is likely that a system of this kind will be brought forward. The Bostedo Package and Cash Carrier Company, of Chicago, has designed such a system for transmission of large packages over long distances. It is proposed to use tubes from 18 to 30 inches in diameter, a size large enough to carry the largest mail bags and it is also claimed that the principles involved may be applied advantageously to tubes of any size down to six inches in diameter.

In designing the system the first consideration was to do away with the friction of sliding carriers through the tubes, as is the practice with smaller tubes. In order to do this a carrier was designed mounted upon large wheels, the diameter of each wheel to be at least one-half the diameter of the tube, one wheel in front of the receptacle and the other behind it; the wheels to run either in a groove cast in the tube, or on a rail laid in the tube. The receptacle, which is a cylindrical box nearly filling the tube, is prevented from scraping the wall of the tube by four friction rollers, two in front and two behind, set at an angle of about 45 degrees from the vertical axis of the tube. With this construction it is obvious that the tendency of the carrier while moving in a straight line will be to assume a vertical position, the function of the friction rollers coming into play only in turning curves and in the case of the carrier being overloaded on one side.

By the use of ordinary cast iron pipe, another advantage of this system over the systems which use sliding carriers, is that it is unnecessary to bore out the tubes. The tubes will be smooth enough as cast, excepting abnormal roughnesses, which of course should be ground or chipped out. Another advantage is that the packing used will not be a hard problem, as it is not the intention to have the packing actually touch the wall of the tube (except in the terminals). It is sufficient for practical purposes if the packing is within say one-quarter to one-half inch of the wall of the tube, as the proportional area of the clearing space to the cross-sectional area of the carrier is insignificant. Attention is called to the fact, that it is no more possible for a sliding carrier to actually fill the tube than it is here, the difference being that in this case a uniform annular clearance is left all around the carrier, while in the case of a sliding carrier there is actual contact at the bottom of the tube, with the maximum clearance at the top.

Leaving out for the present any description of the switches, the use of which will probably be in the remote future, if at all, we will describe the ordinary system, consisting of a pair of tubes with a power station at one end.

The system can be operated upon either the exhaust or the pressure principle. For the present we will confine our description to the pressure type. In this system the air makes a complete circuit. It is taken by the blowing engine from the incoming tube, and discharged into the outgoing tube, the two being connected at the outer end. The delivering apparatus is the same at both ends, and its operation is as follows: The end of the tube is normally closed by a valve, and at the proper distance back from the end to effect the desired result, is another valve, which is normally open. Still further back from the end of the tube, the air current is diverted from the tube and directed either into the return tube or into the blowing engine, as the case may be. The carrier, arriving at its destination first passes the opening where the air is diverted from the tube. Immediately after passing this opening, it begins to compress the air ahead of it. The parts of the terminal are so proportioned that the carrier is permitted to pass the normally open valve before sufficient pressure has accumulated ahead of the carrier to close said valve. However, immediately after the carrier passes the normally open valve, the compressed air ahead of the carrier closes the valve behind it. After this valve is closed, the carrier, which is still moving forward, begins to rarefy the air behind it; that is, the air which is between it and the valve which has just closed. The difference in pressure between the compressed air ahead of the carrier and the rarefied air behind it, tends to bring the carrier to a stop, while at the same time the difference in pressure in a supply pipe taken from the main tube and the rarefied air behind the carrier, is utilized to open the end valve, which permits the delivery of the carrier out of the tube and on a track. The parts are so proportioned that most of the momentum of the car is absorbed in operating the two valves. Enough momentum is left, however, to cause the carrier to roll a convenient distance out on the track, where it may be unloaded and loaded. The track then leads around towards the mouth of the return tube.

The despatching apparatus is operated by hand, by means of a controlling box analogous to that on a trolley car. The movement of the operator in despatching carriers is even more simple, and is quite similar to that of the trolley car operator. The track leading into the mouth of the return tube is slightly inclined, so that when the carrier is released by the operator, it rolls into the mouth of the return tube. The return tube has two valves, one being at the mouth of the tube and the other at a convenient distance from the mouth. The air supply pipe to the main tube also has a valve which when closed, diverts the air from its normal course, around behind the carrier which has been allowed to roll into the mouth of the tube. We thus have three gates or valves in the despatching apparatus,—the one at the mouth of the tube and the one which diverts the main air current being normally open, and the other valve, which is located some little distance from the mouth of the tube, being normally closed. It is obvious that what is desired after the carrier has rolled into the mouth of the tube is to first close the gate behind it, then open the gate in front of it, and then turn the main air current in behind the carrier in order to propel it into the main tube, where it will be caught by the constant main current; and then to return the three gates to their normal positions. All of this is effected by operating these three gates with pistons, the opposite ends of the cylinders for the three pistons all

being connected with the controlling box, and the controlling box also being connected with the main pipe. The controlling box is so arranged that the operator may at will reverse any of the gates, this being effected by the difference in pressure of the atmosphere and the air in the supply pipe from the main; the controlling box being so constructed that the operator, by moving a lever, can put one end of the cylinder which he desires to operate, in communication with the pressure main, and the other end at the same time in communication with the atmosphere.

There are many details of design which it is our purpose to illustrate and describe in a subsequent issue.

We have been publishing for some time an abstract of patents granted in the United States each month on pneumatic appliances. In the space available for this purpose it is impossible for us to give more than a brief description of each patent, with the serial number and the name and address of the inventor. Should parties desire more information, they may get it by communicating with us. We are ready to furnish complete printed copies of the specifications and drawings for twenty-five cents each. Mr. Grafton L. McGill, our representative at Washington, who prepares this matter for us has made an exhaustive search of the files and records of the Patent Office with a view of preparing a list of all old patents on pneumatic appliances. This list is now nearly complete and it is our purpose to begin its publication in the March number. It will be of value to those interested in compressed air, as it will represent the line of thought followed by inventors, and we trust it may disclose some valuable ideas to our readers.

The Flow of Compressed Air in Pipes

[Continued.]

BY WILLIAM COX.

In the last number of COMPRESSED AIR the application of D'Arcy's formula to the flow of compressed air (an elastic fluid) in pipes was shown in detail. In this number a copyrighted table of values of $\sqrt{\frac{p_1 - p_2}{w_1}}$ is given, which both facilitates and simplifies very considerably the use of the formula. Making a separate term of the above we obtain the complete formula in this simpler form

$$D = \frac{c \sqrt{d^5}}{\sqrt{l}} \times \sqrt{\frac{p_1 - p_2}{w_1}} \quad \ldots (9).$$

in which

- D = volume of compressed air discharged at final pressure in cubic feet per minute,
- d = actual diameter of the pipe in inches,
- l = length of the pipe in feet,
- c = a coefficient varying with the diameter of the pipe (see Table II),
- p_1 = initial gauge pressure in pounds per square inch,
- p_2 = final gauge pressure in pounds per square inch,
- w_1 = density or weight in pounds per cubic foot of the air at the initial pressure p_1 when entering the pipe (see Eq. (7) and Table IV).

Values of $c \sqrt{d^5}$ for various sizes of pipe are given in Table II, page 359 of the last number, and values of $\sqrt{\frac{p_1 - p_2}{w_1}}$ for any final pressure p_2 from 20 to 100 pounds, and for any loss of pressure from 1 to 10 pounds are given in Table VI, as follows:

* Table of Values of $\sqrt{\frac{p_1 - p_2}{w_1}}$ in D'Arcy's formula $D = c\sqrt{\frac{d^5 \times (p_1 - p_2)}{w_1 \times l}}$, for terminal pressures from 20 to 100 pounds, and for pressure losses from 1 to 10 pounds.

Compiled by William Cox.

Final Pressure p_2	Losses of Pressure, equals $p_1 - p_2$.										Final Pressure p_2
	1 lb.	2 lb.	3 lb.	4 lb.	5 lb.	6 lb.	7 lb.	8 lb.	9 lb.	10 lb.	
20 lbs	2.325	3.241	3.918	4.466	4.930	5.336	5.693	6.014	6.309	6.574	20 lbs
21 .	2.293	3.198	3.868	4.410	4.870	5.272	5.627	5.946	6.237	6.502	21 .
22 .	2.262	3.157	3.819	4.356	4.812	5.211	5.564	5.878	6.168	6.432	22 .
23 .	2.233	3.117	3.772	4.304	4.756	5.152	5.501	5.814	6.102	6.362	23 .
24 .	2.205	3.079	3.727	4.254	4.702	5.093	5.440	5.752	6.036	6.296	24 .
25 .	2.178	3.042	3.684	4.206	4.649	5.036	5.381	5.688	5.973	6.233	25 .
26 .	2.152	3.007	3.642	4.158	4.597	4.981	5.323	5.630	5.913	6.173	26 .
27 .	2.127	2.973	3.601	4.112	4.548	4.928	5.268	5.572	5.856	6.113	27 .
28 .	2.103	2.939	3.561	4.068	4.499	4.877	5.215	5.518	5.799	6.056	28 .
29 .	2.079	2.907	3.523	4.024	4.452	4.828	5.164	5.466	5.745	5.999	29 .
30 .	2.056	2.876	3.485	3.982	4.408	4.781	5.114	5.414	5.691	5.942	30 .
31 .	2.034	2.844	3.448	3.942	4.365	4.735	5.066	5.364	5.637	5.888	31 .
32 .	2.012	2.815	3.414	3.904	4.323	4.690	5.019	5.312	5.586	5.834	32 .
33 .	1.991	2.786	3.381	3.866	4.282	4.646	4.971	5.264	5.535	5.782	33 .
34 .	1.971	2.759	3.348	3.830	4.242	4.603	4.926	5.216	5487	5.733	34 .
35 .	1.952	2.733	3.317	3.794	4.202	4.561	4.881	5.170	5.439	5.686	35 .
36 .	1.933	2.707	3.286	3.758	4.164	4.520	4.839	5.126	5.394	5.639	36 .
37 .	1.915	2.682	3.255	3.724	4.126	4.480	4.797	5.084	5.349	5.594	37 .
38 .	1.897	2.656	3.225	3.690	4.090	4.441	4.757	5.042	5.307	5.550	38 .
39 .	1.879	2.632	3.196	3.658	4.054	4.404	4.717	5.002	5.265	5.509	39 .
40 .	1.862	2.608	3.168	3.626	4.020	4.368	4.680	4.962	5.226	5.468	40 .
41 .	1.845	2.585	3.140	3.596	3.987	4.333	4.643	4.924	5.187	5.426	41 .
42 .	1.829	2.563	3.114	3.566	3.956	4.299	4.609	4.888	5.148	5.385	42 .

* Copyright 1898 by The Ingersoll-Sergeant Drill Co., New York.
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Final Pressure. p_2	Losses of Pressure, equals $p_1 - p_2$. 1 lb.	2 lb.	3 lb.	4 lb.	5 lb.	6 lb.	7 lb.	8 lb.	9 lb.	10 lb.	Final Pressure. p_2
43 lbs	1.813	2.542	3.098	3.538	3.924	4.267	4.575	4.852	5.109	5.344	43 lbs
44	1.798	2.521	3.064	3.510	3.895	4.235	4.540	4.814	5.070	5.306	44
45	1.783	2.501	3.040	3.484	3.866	4.203	4.506	4.778	5.034	5.268	45
46	1.769	2.481	3.017	3.458	3.837	4.171	4.471	4.744	4.998	5.230	46
47	1.755	2.462	2.995	3.432	3.808	4.139	4.439	4.710	4.962	5.192	47
48	1.742	2.444	2.972	3.406	3.779	4.109	4.408	4.676	4.926	5.155	48
49	1.729	2.426	2.950	3.380	3.752	4.080	4.376	4.642	4.890	5.120	49
50	1.716	2.407	2.927	3.356	3.725	4.051	4.344	4.608	4.857	5.085	50
51	1.703	2.389	2.906	3.332	3.698	4.022	4.313	4.578	4.824	5.050	51
52	1.690	2.372	2.886	3.308	3.671	3.993	4.283	4.546	4.791	5.015	52
53	1.678	2.355	2.865	3.284	3.645	3.965	4.254	4.516	4.758	4.983	53
54	1.666	2.338	2.844	3.260	3.620	3.938	4.225	4.484	4.728	4.952	54
55	1.654	2.321	2.823	3.238	3.596	3.911	4.196	4.456	4.698	4.920	55
56	1.642	2.304	2.804	3.216	3.571	3.885	4.169	4.428	4.668	4.889	56
57	1.630	2.289	2.785	3.194	3.547	3.860	4.143	4.400	4.638	4.860	57
58	1.619	2.273	2.766	3.172	3.524	3.835	4.117	4.372	4.611	4.832	58
59	1.608	2.258	2.747	3.152	3.502	3.811	4.091	4.346	4.584	4.803	59
60	1.597	2.242	2.730	3.132	3.479	3.787	4.066	4.320	4.557	4.775	60
61	1.586	2.228	2.712	3.112	3.458	3.764	4.042	4.294	4.530	4.747	61
62	1.576	2.214	2.695	3.092	3.437	3.742	4.019	4.268	4.503	4.718	62
63	1.566	2.200	2.678	3.074	3.417	3.720	3.995	4.244	4.476	4.693	63
64	1.556	2.186	2.662	3.056	3.397	3.698	3.971	4.220	4.452	4.668	64
65	1.546	2.173	2.647	3.038	3.376	3.676	3.948	4.196	4.428	4.642	65
66	1.537	2.160	2.631	3.020	3.356	3.654	3.926	4.172	4.404	4.617	66
67	1.528	2.147	2.615	3.002	3.337	3.634	3.905	4.150	4.380	4.592	67
68	1.519	2.134	2.600	2.984	3.318	3.615	3.884	4.128	4.356	4.566	68
69	1.510	2.122	2.584	2.968	3.300	3.596	3.863	4.104	4.332	4.541	69
70	1.501	2.100	2.570	2.952	3.283	3.576	3.842	4.082	4.308	4.516	70
71	1.492	2.098	2.556	2.936	3.265	3.556	3.820	4.060	4.284	4.494	71
72	1.484	2.086	2.543	2.920	3.247	3.537	3.799	4.038	4.263	4.471	72
73	1.476	2.075	2.529	2.904	3.229	3.517	3.778	4.018	4.242	4.449	73
74	1.468	2.064	2.515	2.888	3.211	3.498	3.759	3.998	4.221	4.427	74
75	1.460	2.052	2.501	2.872	3.193	3.480	3.741	3.978	4.200	4.405	75
76	1.452	2.041	2.487	2.856	3.177	3.463	3.723	3.958	4.179	4.383	76
77	1.444	2.030	2.473	2.842	3.162	3.446	3.704	3.938	4.158	4.361	77
78	1.436	2.019	2.461	2.828	3.146	3.429	3.686	3.918	4.137	4.339	78
79	1.428	2.009	2.449	2.814	3.130	3.412	3.667	3.898	4.116	4.317	79
80	1.421	1.999	2.437	2.800	3.115	3.395	3.648	3.878	4.095	4.294	80
81	1.414	1.989	2.425	2.786	3.099	3.377	3.630	3.858	3.074	4.272	81

Final Pressure, p_2	Losses of Pressure, equals $p_1 - p_2$.										Final Pressure, p_2
	1 lb.	2 lb.	3 lb.	4 lb.	5 lb.	6 lb.	7 lb.	8 lb.	9 lb.	10 lb.	
82 lbs	1.407	1.979	2.413	2.772	3.084	3.360	3.611	3.840	4.053	4.253	82 lbs
83 "	1.400	1.969	2.401	2.758	3.068	3.343	3.593	3.820	4.035	4.234	83 "
84 "	1.393	1.959	2.388	2.744	3.052	3.326	3.575	3.802	4.017	4.215	84 "
85 "	1.386	1.949	2.376	2.730	3.037	3.310	3.559	3.786	3.999	4.196	85 "
86 "	1.379	1.939	2.364	2.716	3.022	3.294	3.543	3.768	3.981	4.177	86 "
87 "	1.372	1.929	2.352	2.702	3.008	3.279	3.527	3.752	3.963	4.158	87 "
88 "	1.365	1.920	2.340	2.690	2.994	3.265	3.511	3.734	3.945	4.139	88 "
89 "	1.358	1.910	2.330	2.678	2.981	3.250	3.495	3.718	3.927	4.120	89 "
90 "	1.351	1.901	2.319	2.666	2.967	3.235	3.479	3.700	3.909	4.101	90 "
91 "	1.345	1.893	2.309	2.654	2.954	3.221	3.463	3.684	3.891	4.082	91 "
92 "	1.339	1.884	2.298	2.642	2.940	3.206	3.447	3.666	3.873	4.064	92 "
93 "	1.333	1.876	2.288	2.630	2.927	3.191	3.432	3.650	3.855	4.048	93 "
94 "	1.327	1.867	2.278	2.618	2.914	3.177	3.416	3.634	3.840	4.032	94 "
95 "	1.321	1.859	2.267	2.606	2.900	3.162	3.401	3.618	3.825	4.016	95 "
96 "	1.315	1.850	2.257	2.594	2.887	3.148	3.387	3.604	3.810	4.000	96 "
97 "	1.309	1.842	2.246	2.582	2.873	3.135	3.373	3.590	3.795	3.984	97 "
98 "	1.303	1.833	2.236	2.570	2.862	3.123	3.360	3.576	3.780	3.969	98 "
99 "	1.297	1.825	2.226	2.560	2.851	3.110	3.347	3.562	3.765	3.953	99 "
100 "	1.291	1.817	2.217	2.550	2.840	3.098	3.334	3.548	3.750	3.937	100 "

Intermediate Values can be obtained by Interpolation.

A few practical examples are now given to show the application of the formula, and also the use of Table VI. The simplicity by which solutions are obtained of what would otherwise be very tedious calculations, will be seen to be most striking.

EXAMPLE 1. How many cubic feet of compressed air will be discharged from an 8-inch pipe, 10,000 feet long, the initial pressure being 80 pounds, and the loss of pressure not to exceed 4 pounds? Also what will be the volume of equivalent free air?

Here $p_2 = 76$ lbs.

$c_1\sqrt{d^5} = 10988$ (Table II.)

$\sqrt{\frac{p_1 - p_2}{w_1}} = 2.856$ (Table VI.)

and $\sqrt{\frac{1}{l}} = \sqrt{\frac{1}{10000}} = 100.$

Therefore by Eq. (9) we have

$$D\ \frac{10988}{100} = 2.856$$

— 314 cubic feet compressed air per minute at 76 lbs. final pressure.

Now by Eq. (8) and Table V we have

$$F = D \times 6.168 = 314 \times 6.168$$
$$= 1936.7 \text{ cubic feet equivalent free air.}$$

EXAMPLE 2. It is required to transmit through a pipe 7056 feet long, the equivalent of 800 cubic feet of free air, the initial pressure being 60 lbs., and the loss of pressure not to exceed 5 lbs. What must be the diameter of the pipe?

Here $p_2 = 55$ lbs.,

$$\sqrt{\frac{p_1 - p_2}{w_1}} = 3.596 \text{ (Table VI.)}$$

and $\sqrt{l} = \sqrt{7056} = 84.$

Now by transposing Eq. (8) and by Table V,

$$D = \frac{F}{w_2} = \frac{800}{4.74}$$
$$= 169 \text{ cubic feet compressed air discharged at 55 pounds final pressure.}$$

Then by transposing Eq. (9) we have

$$c\sqrt{d^5} = D \times \sqrt{l} \div \sqrt{\frac{p_1 - p_2}{w_1}} \ldots (10).$$
$$= \frac{169 \times 84}{3.596} = 3947$$

We now see from Table II that this value 3947 corresponds to a pipe about 5½ inches diameter. A 6-inch pipe should therefore be selected.

EXAMPLE 3. It is desired to lay a 9-inch pipe, 10,000 feet long, which shall discharge 400 cubic feet of air per minute compressed to 60 lbs. final gauge pressure. What will be the loss of pressure? Also what must be the initial pressure?

Here $D = 400,$
$d = 9,$
$c\sqrt{d^5} = 14872,$ (Table II.)
$p_2 = 60,$
$\sqrt{l} = \sqrt{10000} = 100$

whence it is required to find $p_1 - p_2$ and also p_1.

This problem is the most tedious one which presents itself in connection with the flow of compressed air in pipes, seeing that, as has been shown in connection with Eq. (4) p_1 and w_1, which are unknown quantities, are inter-dependent, each one having a different value as the value of the other one varies. By the usual method we cannot proceed directly but must adopt an indirect or tentative method of solution. With Table VI, however, the problem is exceedingly simple. Thus, transposing Eq. (9) we have

$$\sqrt{\frac{p_1 - p_2}{w_1}} = \frac{D \times \sqrt{l}}{c\sqrt{d^5}} \ldots (11.$$
$$= \frac{400 \times 100}{14872}$$
$$= 2.690.$$

Now looking at the table along final pressure $p_2 = 60$ lbs. we see that

$$\sqrt{\frac{p_1 - p_2}{w_1}}$$

is equal to 2.242 for a loss of 2 lbs.,
and 2.730 " " " " 3 "

so that for 2.690 the proportionate loss $p_1 - p_2$ will be 2.9 lbs., thus making the required initial pressure p_1 to be $60 + 2.9 =$ 62.9 lbs., or say 63 lbs.

If it should now be desired to find the equivalent volume of free air necessary to supply the required volume of compressed air, so as to ascertain what should be the capacity of the compressor, we have from Table V

$$\left.\begin{matrix}\text{Free Air required} \\ \text{at Compressor} \ldots\end{matrix}\right\} = 400 \times 5.08$$
$$= 2032 \text{ cubic feet}$$

of free air to be compressed to 63 lbs. initial gauge pressure. Dividing this by 5.284 (the relative value of w_1 for $p_1 = 63$ lbs., according to Eq. (8) gives 384.5 cubic feet per minute as the volume of compressed air required to enter the pipe at 63 lbs. initial gauge pressure, and which, owing to the loss of pressure caused by the friction in the pipe, expands to 400 cubic feet per minute at 60 lbs. final or exit pressure.

Of course it must be understood that in these calculations no allowances are made for losses other than those caused by friction in the pipe. Should the existence of leak-

age or any other losses be known, such as between the compressor and the receiver, or the receiver and the entrance to the pipe, bends, etc., they must be ascertained and allowed for separately, by the introduction into the compressor of a proportionately greater volume of free air.

A few more examples will be given in the next article, as also some deductions which a closer study of the formula brings to our notice.

For the benefit of those readers who may not have received the last number of COMPRESSED AIR, and in order that the article in the present number may be complete in itself, we here append the formulas and tables which were given in the last number, and to which reference is here made.

EQUATION (7).

$$w_1 = 0.0761\ (0.068\ p_1 + 1.)$$

where w_1 = density or weight in lbs. per cu. foot of the fluid at the initial pressure p_1.

EQUATION (8).

$$F = D \times w_2$$

in which D = volume of compressed air discharged at final pressure, p_2.

F = equivalent volume of free air,

w_2 = density of the discharged air in atmosph's, $= (0.068\ p_2) + 1$,

p_2 = final gauge pressure in lbs. per sq. in. of the disch'ged air.

TABLE II.

Diam'r.	C.	$c\sqrt{d^5}$
1 inch		45.3
2 inches		297
3 "		876
4 "		1856
5 "		3298
6 "		5273
7 "		7817
8 inches		10988
9 "		14872
10 "		19480
11 "		24800
12 "		30926
13 "		37898
14 "		45690
15 "		54462
16 "		64102

TABLE IV.

Gauge Pressure.	w_1	$\sqrt{w_1}$
0 pounds	0.0761	0.276
5 "	0.1020	0.319
10 "	0.1278	0.358
15 "	0.1537	0.392
20 "	0.1796	0.424
25 "	0.2055	0.453
30 "	0.2313	0.481
35 "	0.2572	0.507
40 "	0.2831	0.532
45 "	0.3090	0.556
50 "	0.3348	0.578
55 "	0.3607	0.600
60 "	0.3866	0.622
65 "	0.4125	0.642
70 "	0.4383	0.662
75 "	0.4642	0.681
80 "	0.4901	0.700
85 "	0.5160	0.718
90 "	0.5418	0.736
95 "	0.5677	0.753
100 "	0.5936	0.770

TABLE V.

p_2	w_2	p_2	w_2
0 pounds	1.00	55 pounds	4.74
5 "	1.34	60 "	5.08
10 "	1.68	65 "	5.42
15 "	2.02	70 "	5.76
20 "	2.36	75 "	6.10
25 "	2.70	80 "	6.44
30 "	3.04	85 "	6.78
35 "	3.38	90 "	7.12
40 "	3.72	95 "	7.46
45 "	4.06	100 "	7.80
50 "	4.40		

[To be continued.]

Useful Compressed Air Formulas.

In the application of compressed air errors sometimes occur because there are no available rules and formulas which apply to the subject. I have, therefore, prepared the following simple formulas, which I have used in my experience.

RULE TO DESCRIBE THE ISOTHERMAL CURVE, OR TO FIND THE PRESSURE AT ANY POINT IN THE STROKE OF AN AIR COMPRESSOR DURING ISOTHERMAL COMPRESSION OR CONSTANT TEMPERATURE.

Mariotte's law: The pressure of any gas varies in the inverse ratio of the volume, the temperature remaining constant, or

$$(a) \qquad P' = \frac{P}{V}$$

P' being the absolute pressure at any point of the stroke;
P the original absolute presssure;
V the volume corresponding to the required point of the stroke.

Required the pressure at one-half the stroke, compressing isothermally.

$$P' = \frac{15}{\frac{1}{2}} = 30 \text{ lbs. absolute} - 15 = 15 \text{ lbs. gauge pressure.}$$

Required the pressure at seven-eighths of the stroke.

$$P' = \frac{15}{\frac{1}{8}} = 120 \text{ lbs. absolute} - 15 = 105 \text{ lbs. gauge pressure.}$$

Required the pressure at one-quarter of the stroke.

$$P' = \frac{15}{\frac{3}{4}} = 20 \text{ lbs. absolute} - 15 = 5 \text{ lbs. pressure.}$$

Mariotte's law also applies in determining change of pressure in volumes of compressed air due to change of volume.

Given a volume of air, say 1 cu. ft., at a pressure of 30 lbs. on the gauge, what will be the pressure indicated if this air is forced into one-half the space?

$$(b) \qquad P' = \frac{1 \times (30 + 15)}{\frac{1}{2}} = 90 \text{ lbs. absolute} - 15 = 75 \text{ lbs. gauge pressure.}$$

Reversing the problem: Given a volume of air, say 1 cu. ft., at a pressure of 75 lbs. on the gauge, what will be the pressure indicated if this air is expanded to 2 cu. ft.?

$$P' = \frac{1 \times (75 + 15)}{2} = 45 \text{ lbs. absolute} - 15 = 30 \text{ lbs. gauge pressure.}$$

Example: A receiver 3 ft. in diameter and 6 ft. long is filled with compressed air which indicates 60 lbs. on the gauge. What will be the pressure if this volume of air is enclosed in a receiver 4 ft. in diameter and 12 ft. long?

Volume of first receiver $= 3^2 \times .7854 \times 6 = 42.4$ cu. ft.

Volume of second receiver $= 4^2 \times .7854 \times 12 = 150.8$ cu. ft.

$$P' = \frac{42.4 \times (60 + 15)}{150.8} = 21.1 \text{ lbs. absolute} - 15 = 6.1 \text{ lbs. gauge pressure.}$$

The same rule applies in calculating volumes. In dealing practically with compressed air, we speak of pressure above the atmosphere, but in making calculations for volumes serious errors frequently occur because the atmospheric pressure (15 lbs.) is lost sight of.

For instance, a cubic foot of air represents about 15 lbs. absolute pressure, and if we wish to know what volume this cubic foot will occupy when it is subjected to a pressure (isothermally) of 60 lbs. per square inch above the atmosphere, we must figure thus:

$$(c) \qquad V' = \frac{1 \times 15}{60 + 15} = 0.20 \text{ cu. ft.}$$

Given 1 cu. ft. of compressed air at 45 lbs. gauge pressure, what volume will this air occupy when subjected to a gauge pressure of 60 lbs.?

$$(d) \qquad V' = \frac{1 \times (45 + 15)}{60 + 15} = 0.8 \text{ cu. ft.}$$

Free Air.—By free air is meant air at atmospheric pressure, which is about 15 lbs. per square inch at sea level.

Given a volume, say 500 cu. ft., of free air, what volume will this air occupy when compressed (isothermally) to 60 lbs. gauge pressure?

$$V' = \frac{500 \times 15}{60 + 15} = 100 \text{ cu. ft.}$$

Reversing the problem, how much free air is represented by 100 cu. ft. of compressed air at 60 lbs. gauge pressure?

$$V' = \frac{100 \times (60 + 15)}{15} = 500 \text{ cu. ft.}$$

VOLUMES OF FREE AND COMPRESSED AIR FURNISHED BY AIR COMPRESSORS.

Example. The air cylinder of a compressor is 12 ins. in diam., stroke 18 ins. What volume of free air will it furnish (theoretical) when running at 120 revolutions per minute? 120 revolutions represents 360 ft. piston speed per minute.

$12^2 \times .7854 = 113.1$ area in square inches.

$$\frac{113.1 \times 360}{144} = 282.7 \text{ cu. ft. free air.}$$

And by (c) $\dfrac{282.7 \times 15}{60 + 15} = 56.5$ cu. ft. of compressed air at 60 lbs. on gauge.

A rule by which volumes of compressed air may be approximately determined from volumes of free air, is to divide by the number of atmospheres.

For instance, 60 lbs. represents 5 atmospheres (absolute); 500 cu. ft. of free air, divided by 5, equals 100 cu. ft. of compressed air at 60 lbs. gauge pressure.

As pressures are not always given in even multiples of atmospheres, this rule serves only to determine approximate results.

REDUCED EFFICIENCY OF AIR COMPRESSORS AT DIFFERENT ALTITUDES.

The previous figures are based on the pressure of air at sea level, or 15 lbs. (about) per square inch. As air compressors are frequently used at altitudes, it is desirable to know the extent to which an increased altitude affects the capacity of the compressor. Following are the barometric pressures at different altitudes:

	Lbs. per sq. in.
Press'e at ¼ mile above sea level	14.02
" " ½ " " "	13.33
" " ¾ " " "	12.66
" " 1 " " "	12.02
" " 1¼ " " "	11.42
" " 1½ " " "	10.88
" " 2 " " "	9.88

Free air as applied to the volume of a compressor, or the space traversed by the piston, is not affected by change of altitude, but free air when applied to pressures either absolute or indicated, and to volumes of compressed air, is modified according to the density of the air at corresponding points.

Example. Required the volume in cu. ft. of compressed air furnished by an air compressor when at work one mile above sea level. Also, the volume in cu. ft. of free air representing the reduced efficiency of the compressor when at work at this altitude.

Given an air compressor of the following dimensions: Diameter, 12 ins.; stroke, 18 ins.; revolutions per minute, 120.

We have seen by a previous example that this compressor furnishes 282.7 cu. ft. of free air (theoretical) at sea level, and that this volume represents 56.5 cu. ft. of compressed air at 60 pounds on the gauge. If this compressor is used at an altitude of one mile above the sea, what volume of compressed air will it furnish at 60 pounds on the gauge, the speed remaining the same?

Free air furnished by compressor, 282.7 cu ft.

Barometric pressure at altitudes of one mile, 12.02 lbs., then by (c) substituting the reduced barometric pressure we have:

$$V'' = \frac{282.7 \times 12.02}{60 + 12.02} = 47.18 \text{ cu. ft at 60 lbs. on gauge.}$$

And if it is desired to know how many cu. ft. of free air at sea level are represented by 47.18 cu. ft. of compressed air at 60 lbs. we have by

(d) $$V' = \frac{47.18 \times (60 + 15)}{15} = 235.9 \text{ cu. ft.}$$

of free air at sea level, and $282.7 - 235.9 = 46.8$ cu. ft. of free air, representing the reduced efficiency of the compressor when used at altitude of one mile.

In practice, approximate determinations of the reduced efficiency of air compressors are made by deducting the percentage of difference between the barometric pressures of the respective latitudes.

The volume at sea level being 1, that at

¼	mile above sea level will be	....	7% less
½	" " " "	....	11% "
¾	" " " "	....	16% "
1	" " " "	....	20% "
1¼	" " " "	....	24% "
1½	" " " "	....	28% "
2	" " " "	....	34% "

W. L. SAUNDERS.

Improved Pneumatic Tools for Foundry Use.

[A PAPER READ BY MR. GEORGE H. ROBBINS (PHILADELPHIA) AT THE JANUARY, 1898 MEETING OF THE FOUNDRY MEN'S ASSOCIATION.]

The use of pneumatic tools for cleaning and chipping castings is not new. Certain defects in the old style of construction, the want of knowledge of how to operate them, together with the prejudices of ignorant workmen, have resulted in eight cases out of ten in the condemnation of the tools for foundry use. The first thing we will deal with will be the objectionable features of the old style of tools, of which the recoil or kick was the most noticeable. This recoil or kick has done more to prevent the adoption of large size pneumatic tools than anything else, as it has enabled the workman who is afraid of losing his place to say with some appearance of truth, that holding the tool was injurious to him, producing a paralysis of his arm, etc. To this, and here, let me reply that I know of men who have been running pneumatic tools continously for the past five years, and who have not been affected in the slightest by them in any way whatever. The improved Clement valveless tool is so constructed and so evenly balanced that all kick has been eliminated from it, because it has an air cushion so placed that when in operation the workman is really pushing against air, the elasticity of which takes up all shock and vibration.

Another important objection that is made to the old style pneumatic tool is that so many small parts, valves, springs, etc., enter into its construction. Such a number and variety of parts make the tool very delicate and liable to get out of order.

The improved Clement valveless tool consists of but three parts or pieces—a cylinder that is bored out of a solid piece of steel, a hammer or piston made of tool steel and a butt piece or plug to close the end of the cylinder. The only part of it that moves is the hammer, and that is not dependent on the movement of any other part for its own motion. If it is given fair treatment and regularly oiled it can be depended on for a long period of steady and reliable service, and knowing this we are warranted in guaranteeing it against all repairs for two years. This, I trust, shows plainly and conclusively to any investigator that the objectionable features in the pneumatic tool of the past are not to be found in the improved Clement tool of to-day.

Let me now speak a moment of the ignorance of operating, and the prejudice existing against pneumatic tools and the reason therefor. No doubt some of you have had pneumatic tools tested in your foundries and perhaps unsuccessfully. Have you, however, considered in such a case how this test was made? Pneumatic tools are made in many sizes, and to use them to advantage they must be used for the purpose to which they are adapted—that is, a small tool for light work and a large tool for heavy work. Then again, at what air pressure did you try this tool? Do you know whether the pressure used was high enough to develop the efficiency of the tool? And last, but not least, in whose hands was the tool placed for trial? Was he a man who would work for your interests, forgetting his own, or was he opposed to the tool because it was a labor-saving device, and because its adoption was liable to bring about the discharge from employment of himself or some of his shopmates? These are all-important considerations, and may explain to you why the test of pneumatic tools in your shop was a failure, if such it was.

The best way to introduce the tools is to place them in the hands of young men, who are, as a rule, ambitious, and who will take a pride in running a new machine. Let them know that the successful operation of the tool will mean a slight advance in their wages. If on the contrary, however, you give tools to a man who believes only in old hand methods, then the amount of work that he will turn out will be, comparatively speaking, small.

The average amount of work that can be done with these tools is as follows: In removing sand from large and heavy castings, one man with a medium size tool and a broad chisel can readily do as much work in a given time as six men could do by hand methods. One man with a tool can do as much light fine chipping as is usually done by five men in the same period of time; and in rough or heavy chipping one man with the proper size tool can do about the same quantity of work that is generally done by three or four men with the hammer and chisel.

It is sometimes necessary to do chipping to a line, or true surface. A man who is skillful enough to do this class of work with a hammer and chisel can accomplish

just twice as much in the same time by using a pneumatic tube for the purpose. The operator has absolute control over the tools used for this fine work, striking a light or heavy blow as he desires, governing the force of the blows by the simple pressure of his hand, and not by throttle valves, etc., that are so liable to wear out.

If any one should doubt the possibility of the operator being able to cut to a line. or having this perfect control over the tool, it affords me pleasure to refer you to the marble and granite cutter, who not only does the most delicate carving and lettering with the tools, but does it on a substance that is vastly more friable and brittle than cast iron.

An air compressor, and and air receiver, and a lot of different sizes of pipe strung around the shop do not always constitute either an efficient or economical air plant. To get the best results there is required :

1. An air compressor of improved pattern, of sufficient size and power to develop and maintain a steady pressure of 80 to 100 pounds to the square inch.

2. An air receiver of sufficient size to equalize the pulsations of the compressor and to cause the air to flow with uniform velocity to the tools.

3. As air in its passage through the pipes is subject to friction in the same manner as water, it is important that your pipe system be carefully designed, as loss by friction may be quite serious. In calculating such loss it would be well to remember that the difference in pressure between the entrance to the pipe and the point of use, termed in hydraulics "loss of head and power lost," is not applicable to compressed air. Compressed air will lose 10 per cent. of its head, but the loss of power will only be about 3 per cent. The reason for this is simple when you remember that compressed air as it loses in pressure it gains in bulk, and thus in a measure by its increased volume compensates for the diminished pressure.

DISCUSSION.

Mr. Howard Evans—You do not mention the amonnt of power required to drive the compressor, nor state the saving over hand work where the tools are used. You only say that one man can with one tool do so much more work than by hand.

Mr. Robbins—An air compressor of a size sufficient to operate say three tools, 14-ounce hammers, would require 4 horse power to run it—that is, a belt compressor. When a small compressor can be used it is much more economical to run it by belt power than by steam direct. The cost of such a compressor would be in the neighborhood of $180. The cost of the air receiver would be about $40, while the cost of the pipe would depend altogether on the distance the air was to be carried ; if 100 feet, say $5. Three tools of the capacity mentioned would cost say $300. A total cost of about $525 for the equipment.

Mr. Evans—Where people have a compressor in already the adoption of these tools is accompanied by considerable less expense, is it not?

Mr. Robbins—Certainly. I have here a small 2-ounce tool, the earning capacity of which is $900 per annum. That is the earning without the expense. The tools actually save the labor of one man for 300 working days in the year. The outfit I have mentioned is large enough to run six of these tools. In taking sand off castings you would require a broad chisel like this (showing a chisel with about 2-inch cutting edge).

Mr. Messick—Are the tools in use in this city?

Mr. Robbins—Yes. They are used at Cramp's, and at the works of the Warden Manufacturing Company, in both boiler shop and foundry. They are used in shipyards for chipping and calking. When used for calking a man can calk 60 lineal feet per hour ; on boiler work about 40 feet. It makes a tighter joint than is possible by hand, the blows not being so hard, but multitudinous. The tool I have shown you uses 10 feet of air per minute at 80 pounds pressure. It can be operated with a pressure as low as 60 pounds, but high pressure is the best, the resulting work being much more efficient.

Mr. Messick—Did you ever try driving rivets with them?

Mr. Robbins—Yes ; what you call shell rivets ; ⅜-inch cold rivets. A 6-pound hammer will drive them faster than you can put them in the hole.

Mr. Eldridge—Supposing one wished to knock off a riser from a casting, say a riser 2 inches in diameter, would you smooth the casting with the tool as well?

Mr. Robbins—A sledge would be better for knocking off a gate of that size. After the gate is knocked off you can smooth down with the pneumatic tool.

Mr. Evans—Supposing a foundryman having a compressor wished to try these tools, would you give him a trial?

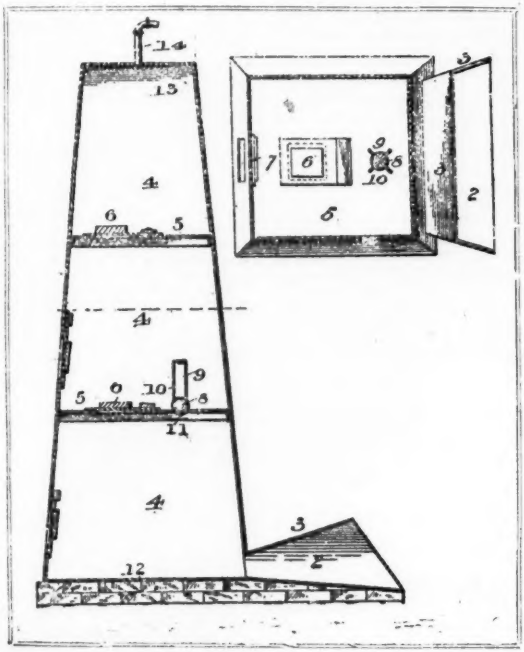
Mr. Robbins—Certainly. He could have them for ten days on trial, and we would visit his foundry and impart all instruction possible.

Mr. R. Toennes, of Boonville, Mo., is the inventor of what he calls a "Wave Air Compressor." The power of the waves is utilized for the purpose of compressing air in a manner quite novel.

Briefly described the invention is as follows:

A shaft or tower, as shown in the larger figure, is constructed on or near the shore of a body of water where there are waves, or a tide. This tower is composed of one or more air-tight chambers (4), as circumstances may demand, and may be constructed of any substantial material.

The tower is built upon a solid foundation of rock. At its base (2) is an opening, with divergent top and side walls. Through this the waves enter the air chamber (4). This chamber is provided with a valve (6). The force of the wave opens this valve and admits the air to the compressing chamber (4). In this chamber is another opening, covered by a ball of some substance of a less specific gravity than water, kept in position by four vertical rods of metal, brought together at the top. As the waves recede, the valve (7) admits air from the outside, thus, by atmospheric pressure, forcing the water out of the chamber. The ball, floating upon the water, closes the opening as soon as the water has escaped. The air which was compressed by the action of the wave is admitted to the storage chamber by a valve (6). With each subsequent action of the water more compressed air is admitted to this storage chamber, thus in a short time affording a reserve force. This is utilized by means of a pipe, provided with a stop-cock (14), by means of which the concentrated power may be transmitted to the point at which it is desired to be used. The numerals (5) represent the horizontal partitions between the chambers; 12 represents the bottom, and 13 the top of the tower.



WAVE AIR COMPRESSOR.

The smaller figure represents a horizontal section of one of the chambers, showing

the manner in which the water valve and the ball (8) operate; 2 is the opening and 3 the outwardly inclined side walls for the admission of the waves.

This principle has never before been used in obtaining compressed air. Aside from the cost of construction, it requires but little outlay, and at the same time is capable of doing good work. It may be used on any body of water where the waves are of sufficient force. On the seashore the desired result may be obtained, where the coast is favorable, by constructing the shaft on the shore, or in the cliffs, and permitting the waves to enter by means of a tunnel, thus obtaining the advantage of cheapness of construction and stability. The tower may consist of one or more chambers, the number and height depending entirely upon the tide and waves.

COMMUNICATION.

Under this heading will be published inquiries addressed to the Editor of COMPRESSED AIR. We wish to encourage our readers in the practice of making inquiries and expressing opinions.

We request that the rules governing such correspondence will be observed, viz: all communications should be written on one side of the paper only: they should be short and to the point.

Editor COMPRESSED AIR:

I regret very much to learn that you are short of back numbers for Vol. No. 1 of COMPRESSED AIR, and will ask you to please forward all such numbers as you have on hand, and credit me with the balance, and in the event you should possibly secure any missing numbers, please forward at a later date. I intend to be a constant subscriber to your valuable paper, appreciating its work in this new field of "Compressed Air."

Yours truly,

A. COLUMBUS SMITH.

347 S. Paulina St., Chicago.

PATENTS GRANTED JANUARY, 1898.

Specially prepared for COMPRESSED AIR from the Patent Office files by Grafton L. McGill, Washington, D. C.

567,023 — Air Lift-Pump. W. L. Saunders, North Plainfield, N. J.

This invention relates to improvements in the art of raising liquids by means of compressed air; and it consists in an improved process and apparatus whereby alternate charges of water and compressed air are delivered to the eduction-pipe at a high initial velocity. The object of the invention is to accomplish the elevation of water or other liquids by means of compressed air or other gases with greater economy than has heretofore been possible. In accordance with this invention the compressed air is not directed into the water in the form of fine streams or jets which would readily commingle therewith, nor is it delivered continuously at the foot of the eduction-pipe, thereby, as asserted by some, dividing the water into piston-like layers the existence of which is doubted, nor is either the air or the water started on its upward journey through the eduction or delivery pipe in a continuous stream; but by means of the arrangement of apparatus and the proper regulation of the pressures of the liquid and the gas employed it is so arranged that masses of the liquid and masses of the gas are started up the delivery pipe in alternation and each with a high velocity, as will appear. Whether the gases and the liquid become more or less intimately commingled before leaving the delivery-pipe is immaterial so long as they start up the delivery pipe with a sufficiently high initial velocity, for it necessarily follows that if so started and the supply of air and water in alternation be maintained with sufficient frequency the velocity of the inflow will communicate itself to the rising column, and as the same rises the superincumbent pressure will be reduced and the masses of compressed gas by expansion will assist in the expulsion of the liquid above them.

596,822 — Apparatus for Increasing Efficiency of Compressed Air. John McIntyre, Jersey City, N. J.

A casing is adapted to contain the condensing liquid. A tube extends into the latter to form a combustion-chamber within the tube and a vapor-chamber around the tube. The combustion and vapor-chambers have their bottoms formed by the condensing liquid. The combustion-chamber is supplied with air and combustible gas through the nozzle of a fuel pipe. An igniting-chamber having valved connection with the top of the combustion-chamber is provided with electrodes which are adapted to spark and ignite the moist gas admitted into the igniting-chamber through the valved connection. The products of combustion pass through the liquid to the vapor-chamber, which latter is provided with an outlet-pipe connecting with the motor.

596,470—Drier. K. S. Blanchard, Albion, N. Y.

A casing is provided with a series of longitudinal compartments having slated conveying aprons located therein, the aprons being rotated upon rollers. A series of cleaning aprons under the conveying aprons serve to sweep the floors of the compartments. A series of slots is arranged in the casing above the aprons for the entrance of forced currents of air laterally across the aprons, those on one side of the casing alternating with those on the other, while a corresponding series of ventilating slots is located between the layers of aprons. A blower communicates with an air-trunk on the casing. Pipes leading from the air-trunk are provided with nipples opening through the casing above the aprons.

596,655—Grain Drier. W. E. Ellis, Detroit, Mich. Assignor of one-half to T. Hurley, same place.

This invention consists of an enclosing case, and a series of vertical alternate grain and air-spaces

divided by perforated walls, crossing said case transversely. These air-spaces are closed at the top and bottom and open at their opposite ends, while the grain-spaces are closed at their ends and open at the top and provided with a discharge-opening at the bottom. The induct air-chamber on one side of the case extends the full length of the latter and is common to all of said air-spaces, while an educt air-chamber corresponding to the induct is also common to all of said air-spaces. A series of vertical dampers control the openings of the air-spaces into the induct and educt chambers respectively, whereby the blast may be caused to enter at one end of said air-spaces, pass through the body of the interposed grain, and out of the opposite end of the succeeding air-space into the educt-chamber. The air-spaces are provided with a series of horizontal strips upon which said wall or screen is mounted, and vertical slides at their top for cutting off the air-supply.

596,967 — Refrigerator. J. H. Barrett, Grand Rapids, Mich.

An air-chamber is secured to the under surface of the cover, having a removable bottom provided with an opening which communicates with the ice-chamber.

597,223—Air-Compressor. T. H. Roberts, Detroit, Mich.

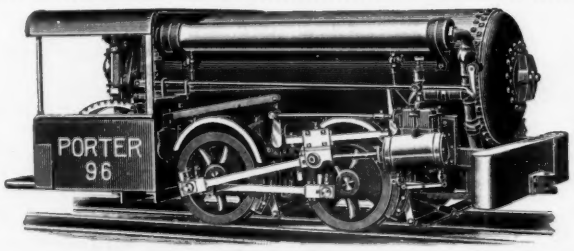
An air-tank is formed of two sections with an air-pump secured between them, said pump having its cylinder formed with supporting means fitted in and secured between the sections of the tank and provided with a series of air-inlet passages extending through said supporting means into the cylinder. Valves are seated on the ends of the pump-cylinder, and a reciprocating piston having a piston-rod extends through a stuffing-box in the tank and is operated by drive-mechanism supported on the tank.

597,543—Lumber Drier. H. J. Morton, Chicago, Ill.

The drier consists of housing, receiving and discharging air through its roof, and having laterally-extended air-passage-ways under the roof. Studding extends along the middle line of this roof and rests upon the rafters of the drier. Parallel, longitudinally-extending, perpendicular walls in combination with the studding and rafters, form a series of air-discharge compartments through which holes lead to the top of the drier. Longitudinally-moveable planks are arranged on said top and provided with holes designed to register with the openings through the top of the compartments by sliding the planks. A series of air-outlets is formed similarly to the air-discharge compartments and extend longitudinally along the middle of the roof, while a series of air-inlets discharging into the laterally-extending air-passage-ways is obtained adjacent to, and on each side of the air-outlets.

597,666—Air-Valve. S. C. Arnold, Denver, Col. Assignor to The Nat. Specialty Mfg. Co., same place.

A valve-float consists of two tubes, one enclosed within the other, and connected by two separated diaphrams which form an air-tight chamber. Both tubes are open at the bottom, the outer one having an orifice in the lower part of its wall and closed at the top by the upper diaphram, while the inner tube projects above the upper diaphram and has an orifice provided with a valve in its upper portion, said valve being operated by the float.



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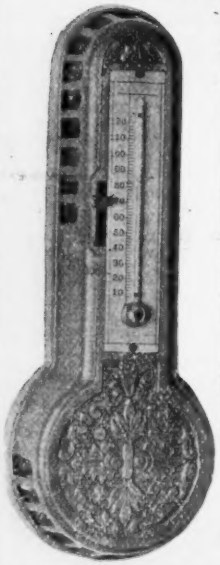

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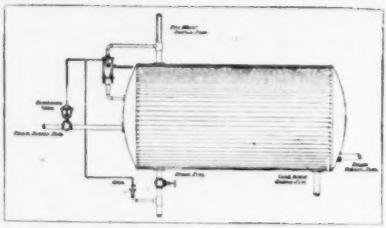

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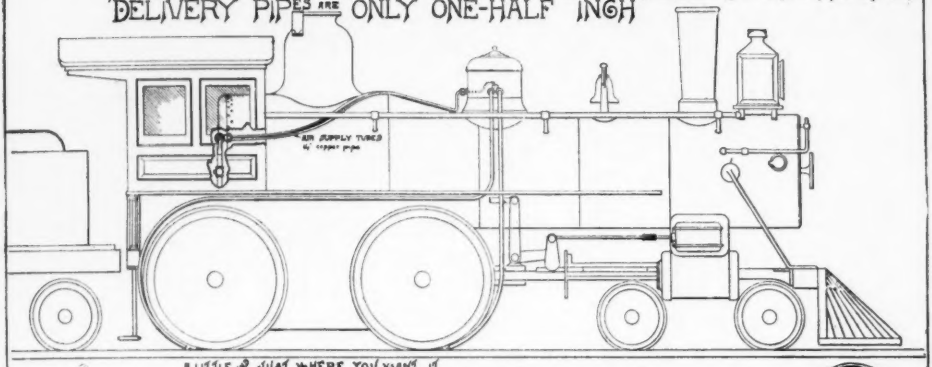

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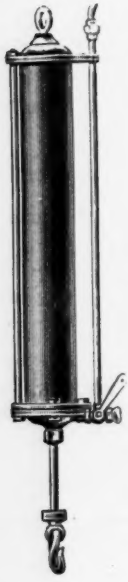

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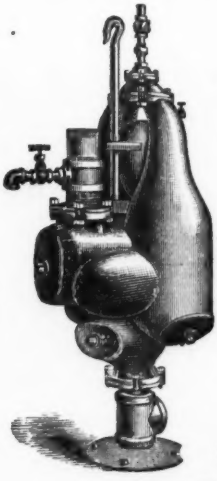

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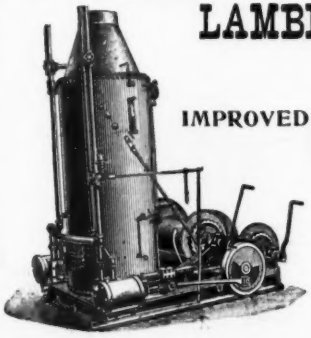

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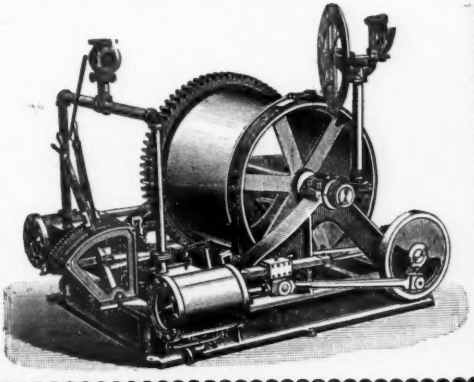

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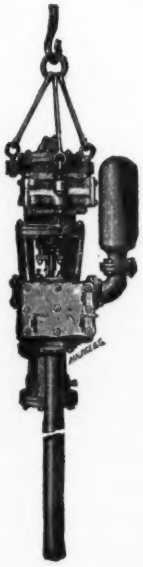

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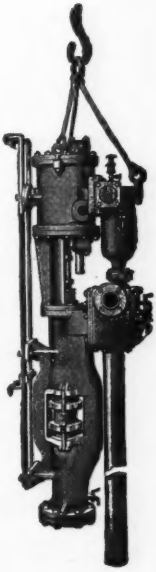

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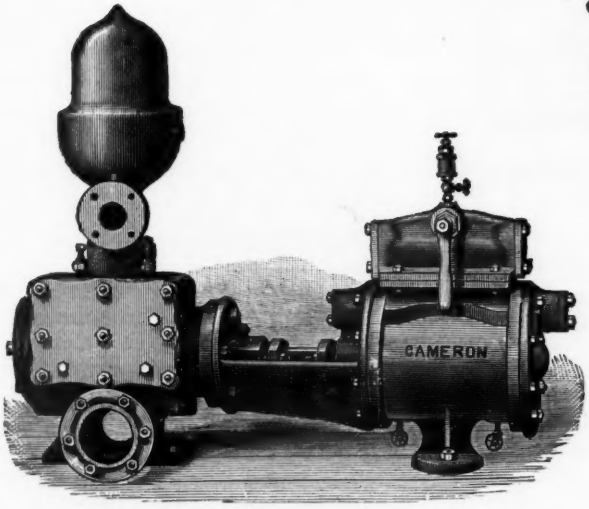

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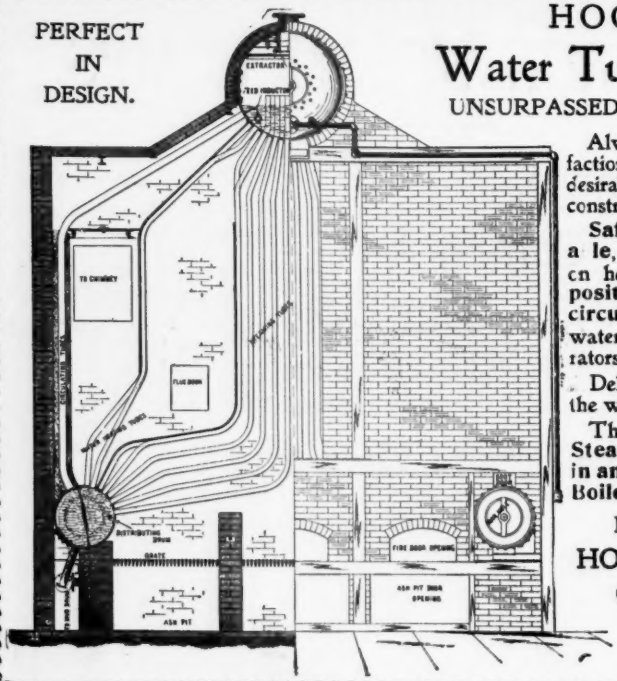

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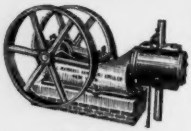

CLASS E.

VARIED SIZES AND TYPES

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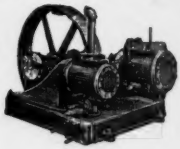
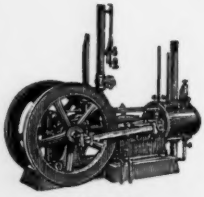


CLASS J.

AIR COMPRESSORS

The types shown here are used in Shops and Mines, or Quarries. Catalogues show a great variety of Machines for Compressing Air. Recent orders from Penn. R. R., Cambria Iron Co., Newport News Shipbuilding Co., Etc., Etc.



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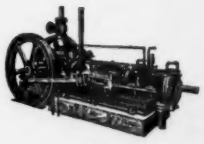

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